

A Spectromicroscopy Study of the Al/GaS Interface: An Evidence of Band Bending Lateral Inhomogeneities.

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ABSTRACT

Spectromicroscopy study has been performed to find evidence of lateral inhomogeneities in the band bending for the Al/GaS system. Micro-images of the interface tuned to the Al 2p core levels revealed localized chemical inhomogeneities in proximity of the edge of the Al overlayer. A careful analysis of the photoemission spectra supports these conclusions and relates the inhomogeneities to band bending variations.

INTRODUCTION

In the past 50 years, the problem of interface barriers, both for Schottky barriers and heterojunctions has been one of the main topics in solid state physics [1,2,3]. This problem is still open and, in particular, there is no complete explanation of how interface phenomena affect the barriers. Many models and theories were developed over the years to tackle the problem and to obtain a unified picture [4,5,6]. The attention to this problem is due not only to the technological impact of semiconductor devices but also to many relevant fundamental questions. A good theory for explaining the barrier requires in fact knowledge of both the interface electronic structure and of the “absolute” interface energy scale (e.g., the mid-gap energy) [7,8].

The main objective of the present work is to detect lateral inhomogeneities of the band bending via high resolution spectromicroscopy and to show that the elementary Schottky picture breaks down when the interface is probed with sufficient spatial and energy resolution. Spectromicroscopy studies in this domain with high lateral resolution are still quite scarce [9].

EXPERIMENT

The single crystal GaS are grown at Ecole Polytechnique Fédérale of Lausanne (Switzerland). GaS is a layered compound so cleavage is easy and yields near perfect surfaces. The samples were cleaved in ultra high vacuum at a base pressure $\sim 3 \times 10^{-9}$ mbar. The interfaces were obtained by evaporating $\sim 100\text{\AA}$ thick aluminum metal on a half masked sample at 10^{-9} mbar. An Al-overlayer edge width obtained with this method ranged from 2-15 μm . The spectromicroscopy was performed at a base pressure of 1.0×10^{-10} mbar. The elemental and morphological information is obtained via photoemission microscopy performed at MAXIMUM at BL 12.0.1 at the ALS, Berkeley. The MAXIMUM microscope has achieved unprecedented lateral resolution of $0.1\mu\text{m}$ and a nominal energy resolution of 0.25 eV at 130 eV photon energy.

RESULTS

A $20 \times 20 \mu\text{m}^2$ microimage of an Al/GaS interface obtained at Al $2p_{3/2}$ core level by focusing 130 eV undulator beam down to a submicrometric size on the sample is shown in the fig.1 (a). Al overlayer signal inhomogeneities are clearly visible in the image along the entire overlayer border - see the bright “bubbles“ on the image - suggesting

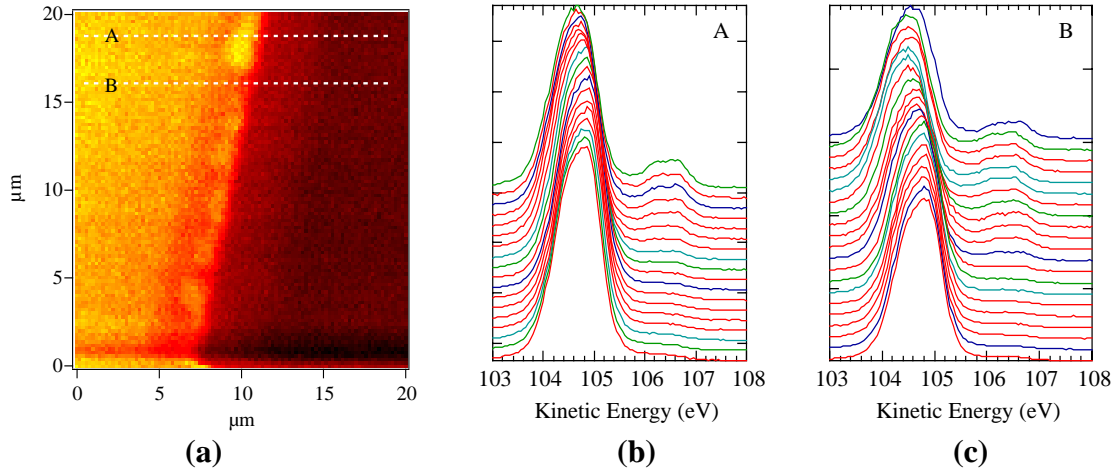


Figure 1. (a) $20 \times 20 \mu\text{m}^2$ microimage tuned at the Al $2p_{3/2}$ core level of the Al/GaS. The bright areas correspond to the Al covered area while the dark areas correspond to the metal-free area. (b) and (c) Ga 3d spectra obtained at along the dashed A and B lines in (a), respectively.

possible chemical reactions between the substrate and the overlayer. Fig. 1 (b) and (c) are two correlated series of Ga EDCs obtained along lines A and B of fig. 1a. By comparing the two, we see the difference in the band bending along line A and B. Note that line A crosses one of the bright Al overlayer border areas of fig. 1a, whereas line B does not. Valence-band GaS spectra (not shown here) exhibit the same shifts -- i.e., they are related to the GaS band bending changes. From best-fit peak positions we derived the interface band bending. The maximum shift for the GaS features along line A is ~ 150 meV, whereas the Al $2p$ fits give a value of 50 meV for the shift of these levels. This rules out any charging effects. Furthermore, it implies a difference in the Schottky barrier height variations along two lines where Al reactivity to the substrate is different. Also, Fig 1(b) and (c) shows that metallic gallium feature originates at higher kinetic energy, whose intensity increase on going from pure GaS to the Al-rich region indicating the reactivity of Al overlayer with the substrate is thickness dependent.

This band bending and Schottky barrier behavior is related to local chemical inhomogeneities. In fact, a careful analysis of spectra for the bright border regions along line “A” reveals a different chemical composition with respect to the other regions and in particular to the border portion of line B.

CONCLUSION

Our results establish a correlation between local chemical reactions and inhomogeneities in the band bending and in the Schottky barrier. Bright areas were found in the Al 2p microimages along the border of the Al overlayer. The local chemical composition was different in these bright areas with respect to the other border areas. In parallel, the band bending changes (as the Schottky barrier changes) across the Al 2p border were different for the bright areas and for the other border areas. The size of bright areas are up to 5 μm^2 . Similar border features were found for other III-VI compounds, but their size is growth dependent [11].

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